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Calibration of a Three Meter Small Radio Telescope in Baghdad University using the Sun as a Reference Source

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Abstract

The calibration of the three meter Baghdad University Radio Telescope (BURT) has been performed using two types of calibrations: Antenna Position calibration, and Detector calibration. The sun is used as a reference source to calibrate the telescope. The antenna position Azimuth (Az), and Elevation (El) are calibrate according to sun's azimuth and elevation in the date (11/10/2017; at time 10:19 AM). A calibration report is designed to illustrate the calibration parameters for each specific date and time. The detector calibration is representing a study for power spectrum response for the sun according to radio telescope frequency band (1.3 GHz – 1.5 GHz) with central frequency (1.42 GHz). Drift Scan function in the telescope's software is used to draw the sun's radio spectrum at date (23/1/2018; at time 09:57:25 AM).

Keywords: Radio Telescope, 21 cm Hydrogen Emission Line, Antenna Control Unit (ACU)

معايرة التلسكوب الراديوي الصغير ذو القطر 3 أمتار الخاص بجامعة بغداد باستخدام الشمس كمصدر راديوي مرجعي

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الخلاصة

تم معايرة تلسكوب جامعة بغداد الراديوي ذو قطر 3 متر باستخدام نوعين من المعايرة: معايرة موقع الهوائي، و معايرة الكاشف. تم استخدام الشمس كمصدر مرجعي لمعايرة التلسكوب. موقع الهوائي (السمت و الإرتفاع) تم معايرتهم نسبة إلى موقع الشمس في تاريخ (2017/10/11)، في وقت (10:19 صباحاً). بعدها تم تصميم تقرير للمعايرة يفصل بدقة كل تاريخ و وقت للمعايرة. معايرة الكاشف هي دراسة لتوضيح قدرة إستجابة الكاشف للترددات ضمن الحدود المقرر رصدها بالتلسكوب الراديوي (1.3 – 1.5 جيجا هرتز) من ضمنها (1.42 جيجا هرتز). وظيفة مسح الإنجراف في برنامج التلسكوب هي لرسم الطيف الراديوي الشمسي في تاريخ (2018/1/23)، في وقت (9:57:25 صباحاً).

1. Introduction

The radio astronomy system must be initially calibrated before reliable measurements may be made. Moreover, it is advisable that either intermittent or preferably periodic system measurements be made at regular intervals of time in order to ensure proper system operation [1]. Initial calibration consists of many aspects and then a series of final checks based upon astronomical measurements with comparisons to known documented sources which are checked against observations [2].

Calibration of the antenna position is necessary before doing anything with the antenna. Calibration can be done by selecting two recognized sources in the sky such as the Sun, the Moon, any strong radio sources, or a known satellite with emitting frequency in the range of receiver system and then do many steps like, when the shadow of horn is on the center of dish this mean the antenna is calibrated now and it would be recommended to repeat the calibration [3, 4].

2. 21 cm Hydrogen Emission Line

The emission of the neutral hydrogen (HI) at a wavelength of 21 cm is usually used to study various astronomical phenomena. A neutral hydrogen (HI) atom has one proton and one electron. Both particles have quantized total spin (s) of $1/2$ and a spin in the z -direction (m) of either $1/2$ or $-1/2$. Spin-spin coupling is the result. It was discovered in 1945 that what was once thought to be a degeneracy in the ground state of the hydrogen atom is in fact a very fine energy level split between a more energetic parallel spin state $|m_e = -\frac{1}{2}, m_p = \frac{1}{2}$ and a less energetic anti-parallel ground state $|m_e = -\frac{1}{2}, m_p = \frac{1}{2}$ [3]. When a hydrogen atom transitions from the excited state into the ground state, a photon is emitted carrying away the energy difference. This photon has a wavelength of 21 cm [5, 6].

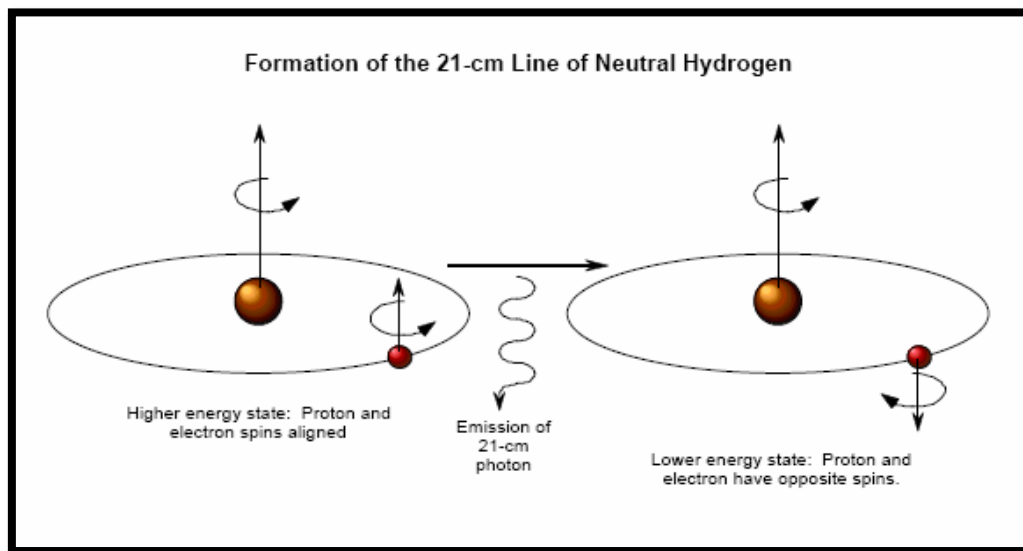


Figure 1-The spin-flip transition of neutral hydrogen atoms [7]

3. The BURT Radio Telescope Calibration

Two types of calibration have been performed for the three meter BURT radio telescope; Antenna Position Calibration, and Detector Calibration by using the sun as a reference source.

3.1 Antenna Position Calibration

In this part the operation description of the Antenna Control Unit (ACU) and the position calibration is made, the procedure is summarized as follows:

In the morning of 11/10/2017, the power switch is pressed to supply the power to the ACU, as shown in Figure-2:



Figure 2-Illustrate the ACU front panel

The Edition Message is displayed on the display screen as shown in Figure-3:



Figure 3-Edition message.

If any key is pressed in display edition message, ACU will enter the "Monitoring" mode. At this time, the main menu for the monitor will be displayed on the screen, as shown in Figure-4:



Figure 4-Main menu for monitor.

The menu is used in the monitoring made for the convenience of set and checkup of the parameters. Confirm the states by pressing the "←" key after the parameters or "selection item" digits are entered, which will show that it is effective.

Press the key "1" when displaying the main menu, the digit will be displayed in "select:", then press the key "←", ACU will enter the Parameters Set Mode, as shown in Figure-5:



Figure 5-Parameters set menu

Press the keys "1" and "←" under the parameters set menu, ACU will enter the angle calibration set menu, as shown in Figure-6:



Figure 6-Set menu for angle calibration.

The angle value displayed on ACU will be a random one which can't represent the real Azimuth, Elevation, and Polarization angles of the antenna. Therefore, the angle must be directly calibration. The method that we used for the calibration is the sun calibration method. First, the antenna is directed towards the sun's position at 10:19 AM. The accurate position of the sun is obtained from an application on mobile phone from NASA called (Mobile Observatory Software) and found that the position of the sun at that time ($Az=147.94^\circ$, $El=44.3^\circ$). The antenna goes to the wrong position ($Az=144.48^\circ$, $El=41.08^\circ$), then by repeating the previous process and inputting the correct position of the sun. The calibration is completed, so the antenna goes to the correct position of the sun. Figure-7 shows the radio telescope before and after the calibration.



Figure 7-The BURT before and after the calibration.

A calibration report paper is designed to describe the telescope position calibration in such specific time. This report gives information about the sun's position (Azimuth, Elevation) at that time. The purpose from this report is to show the verification of the telescope calibration at many times. Figure- 8 shows the calibration report.

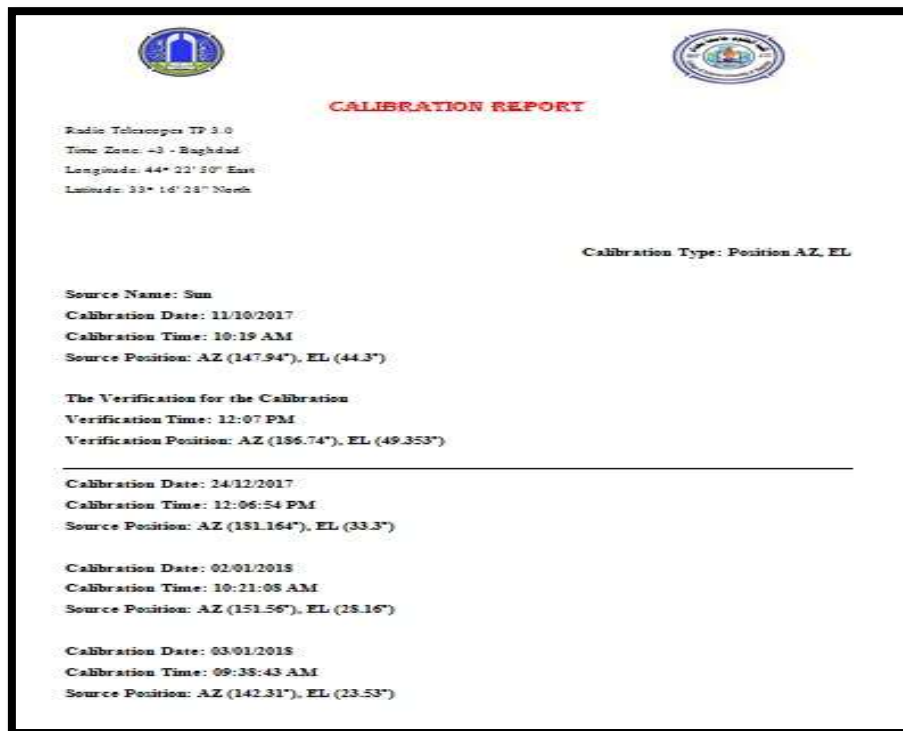


Figure 8-The Calibration Report

3.2 The Detector Calibration

In this part of my work, practically study the detector calibration of the telescope. So the radio telescope detection represents a power spectrum response at frequency range (1.3 GHz – 1.5 GHz) for any radio source by using the Drift Scan Function in the telescope software.

Therefore, the correct position of the sun should be known. Secondly make the antenna with exact elevation of the sun and at last make the sun passes in front of the telescope's antenna by moving the telescope's antenna forward in front of the sun to record the difference in the signal, then go backward, when the sun at (Az=158.67°, El=27.29°) at time 9:57:25 AM (January 23, 2018), and after that we see the recorded data and we notice that the intensity (signal strength) increases when the sun passes in front of the telescope and decreases when the sun is passed away. Figure-9 shows the change in the intensity:

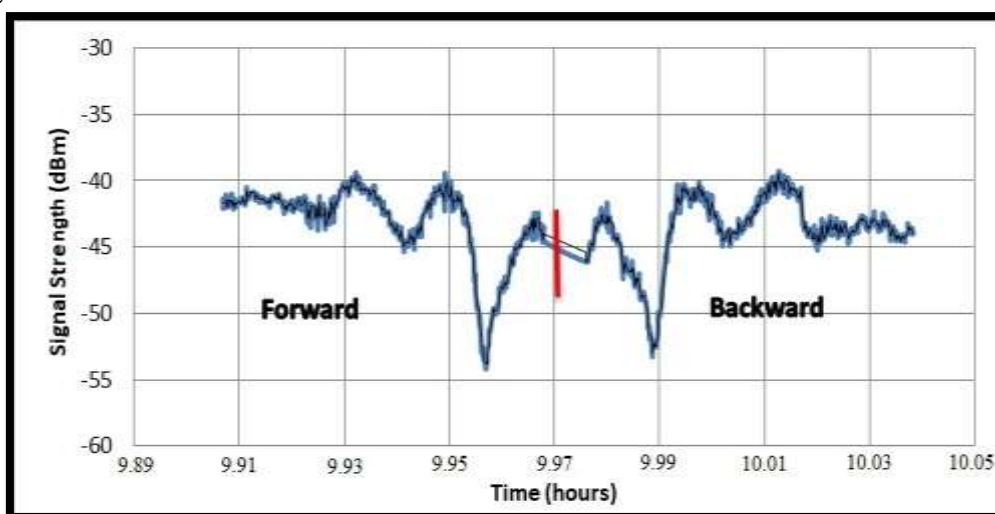


Figure 9-The relation between Time (hours) and Signal strength (dBm), when the telescope crosses the sun forward and backward, the red line represent the time when changing the azimuth to opposite direction.

The two peaks in Figure-9 represents that the antenna movement crosses the sun twice.

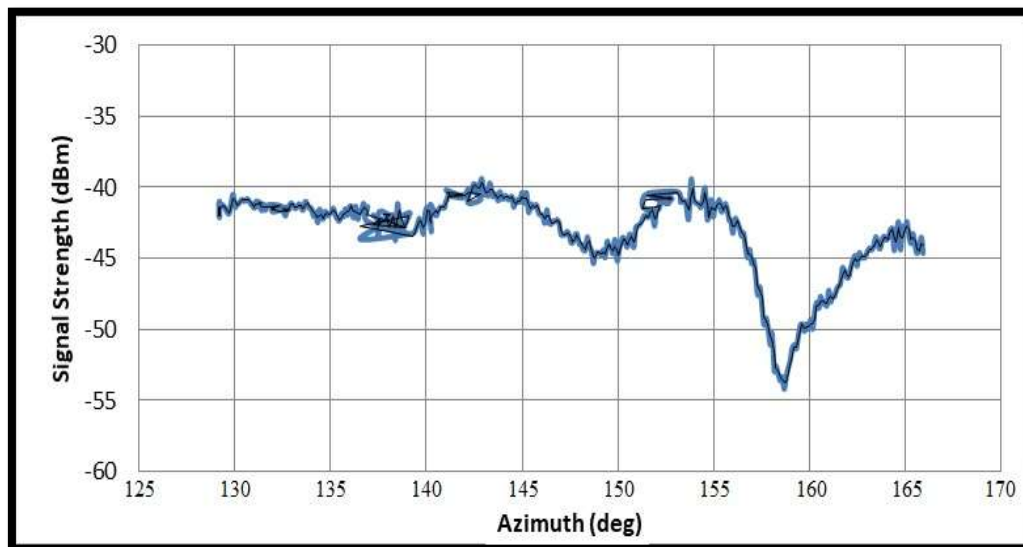


Figure 10-The relation between Azimuth (deg) and Signal Strength (dBm).

Figures-(9, 10) represent that the inverted peaks is when the sun in front the antenna, this clearly means that the receivers are working properly.

So, after that to demonstrate the antenna pattern of BURT radio telescope from the observed spectrum and to compare it with the theoretical antenna pattern, so the maximum intensity achieved is (-54.19 dBm), and the pattern achieves its half-power at (-3 dBm), then the recorded intensity was (\cong -51.08 dBm) and the angle at the half-power is (1.2°), as in Figure-11.

Then calculate the field pattern at 0.707 value of its maximum, and then the intensity was (\cong -38.31 dBm). Finally we calculate the field pattern at 0.5 values of its maximum or at the full width half maximum (FWHM), and then the intensity will be (\cong -27.09 dBm). The purpose of the previous calculations is to determine the antenna power pattern of the telescope (BURT).

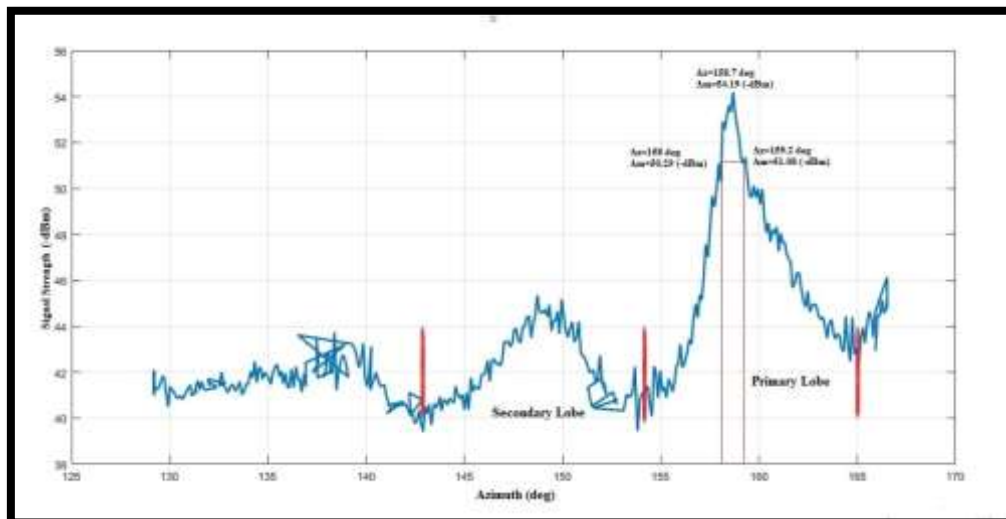


Figure 11-The relation between the Azimuth and Signal Strength, and shows the primary lobe and the secondary lobe to calculate the angular separation of the telescope

Conclusions

A radio telescope is simply a telescope that is designed to receive radio waves from space, unlike the naturally occurring radio emission from stars, galaxies, quasars and other astronomical objects. Its simplest form consists of a parabolic reflector, receiver and detector. In additions, the devices of the telescope have to be calibrated. However, the calibration methods that are used in this work are the

Antenna Position Calibration and the Detector Calibration. By observing a single point source (the sun as a reference source), and when the antenna is aimed directly at the sun, the actual coordinates of the sun is registered to the telescope, this explains the Antenna Position Calibration. And when the antenna is aimed to the sun, it gives a maximum signal, as it is moved away from the sun, the signal decreases, and this explains the Detector Calibration.

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